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RECENT INVESTIGATIONS ON THE CONTROL OF CEDAR-APPLE RUST IN THE HUDSON VALLEY

J. M. HAMILTON

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ABSTRACT

BRIEF reviews are given of the life histories of the apple rust fungus (*Gymnosporangium juniperi-virginianae* Schw.), the hawthorn rust fungus (*G. globosum* Farl.), and the quince rust fungus (*G. clavipes* C. and P.) as they pertain to an appreciation of the rust problem on the apple in the Hudson Valley. The relative importance and status of these three species of rust fungi in the apple production of this area are considered.

Observations on seasonal development indicate that the danger from foliage infection by the apple rust fungus extends over a period from the first of May to the latter part of June. The susceptible period for apple fruit infection is limited, for the most part, to the month of May.

The data presented are limited to field trials for the control of the apple rust fungus. Data were recorded by infection periods rather than at the end of the season.

Commercial control of apple rust in the Hudson Valley can be obtained economically by the use of fungicides. Absolute control was obtained in those instances where no growth occurred between the spray application and the infection period.

Lime-sulfur, wettable sulfurs, bordeaux mixture, and two proprietary copper fungicides were tested. Lime-sulfur (1–100) gave commercial control. All of the wettable sulfurs gave satisfactory control under average conditions, but under adverse conditions those materials that deposited the greatest sulfur residue were the most effective. Flotation sulfur in the paste form and sulfurs to which amendments have been added to promote adhesiveness appeared the most promising. The finer sulfurs (particle size of 5 microns or less) that spread well and had but little run-off were the most effective, depending in a measure on the concentration used. Bordeaux mixture (2–3–100) was effective, but the proprietary copper substitutes, at the concentrations used, were not.

Timeliness and thoroness were obviously vital factors in effective control and apparently were more important than the concentration of the material.

Suggestions are given for adapting the experimental results to commercial practice, especially as to fitting the sprays for apple rust into the customary spray program for apple scab.

If effective spray equipment is not available and if the alternate host, the red cedars, cannot be reduced to a minimum, the most economical policy is that of the substitution of rust-resistant varieties of apples.

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J. M. HAMILTON
Associate in Research (Plant Pathology)

INTRODUCTION

Every season apple rust occurs to some extent thruout the whole Hudson Valley territory. In most orchards, however, it is only a minor trouble and is controlled by the sprays applied for apple scab, but in some districts the disease has become a matter of major concern. In those localities favorable for its development, apple rust has not only been causing heavy annual losses but, what is more important, has been bringing about a rapid degeneration of affected blocks of fruit trees.

Thomas and Mills[1] investigated this problem in 1927 and 1928. They found three species of rust fungi causing destructive diseases of apples in the Hudson Valley. All three spread to the apple from red cedar, the alternate host. Each species is capable of attacking not only the apple, but a wide range of related pomaceous plants, yet each has a preferred host from which its common name is derived. Thus, *Gymnosporangium juniperi-virginianae* Schw. is known as the apple rust fungus, *G. globosum* Farl. as the hawthorn rust fungus, and *G. clavipes* C. and P. as the quince rust fungus.

The apple rust fungus can infect both the foliage and the fruit of the apple, while the hawthorn rust fungus attacks only the foliage and the quince rust fungus only the fruit. The hawthorn rust fungus is rarely severe. The quince rust can, but infrequently does, cause serious commercial losses to the fruit. Foliage infections by the apple rust fungus constitute the big problem; consequently, control of the fungus has been made the principal object of the work reported herein.

The control of apple rust by the eradication of the red cedar (*Juniperus virginianae* L.) is the usual recommendation and has been successfully practiced in some states. This procedure, however, is

[1]Thomas, H. E., and Mills, W. D. Three rust diseases of the apple. *Cornell Univ. Agr. Exp. Sta. Mem. No. 123: 1–21. 1929.*

impractical for the most part under Hudson Valley conditions. Rust resistant varieties of apples offer a second approach to the control of the disease. This measure, tho, is not a complete solution to the problem since apples vary in their susceptibility not only to different species but also to different strains of the rust fungi. Also, growers having established orchards of rust-susceptible varieties can not always afford to remove them and replant with rust-resistant varieties. At present, then, the application of fungicides remains as the chief reliance for commercial control.

Spraying has often been considered impractical as an apple rust control measure, but it was believed that improved spray equipment,

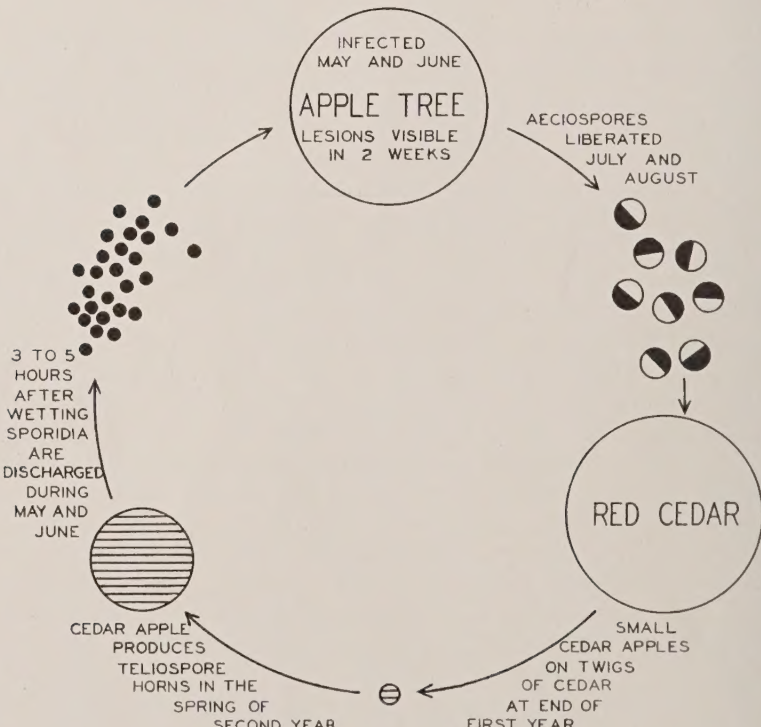

FIG. 1.—DIAGRAMMATIC LIFE CYCLE OF THE APPLE RUST FUNGUS.

Note that the spores produced on the apple (aeciospores) do not re-infect the apple. Only the spores produced on the cedar galls (basidiospores) can infect the apple.

together with a highly efficient spray service, warranted further consideration of spraying as a control measure.

Altho extensive apple rust investigations have been carried out in other areas, it was deemed essential to conduct a project on this problem under the set-up of the Hudson Valley territory. The marked tendency of growers to substitute the milder wettable sulfurs or copper materials for lime-sulfur in the spray program, together with the fact that lime-sulfur is too injurious to the foliage of many of the orchards that have become weakened by successive heavy incidences of rust, necessitated a revaluation of an effective spray schedule for apple rust.

A brief review of the seasonal development of the rust fungi and other facts pertinent to this study will be presented before proceeding with the report of recent spraying trials.

LIFE HISTORIES OF THE FUNGI

The apple and the common red cedar are the two hosts on which the three rusts complete their life histories. The relationships of the

FIG. 2.—"CEDAR APPLE", GALL OF THE APPLE RUST FUNGUS ON THE RED CEDAR.

FIG. 3.—CEDAR GALL OF THE APPLE RUST FUNGUS IN SPORE-PRODUCING STATE.

apple rust fungus and its various spore forms to the two hosts are outlined in the diagram in Fig. 1. This life history typifies, in general, that of the other two rust fungi also.

The familiar "cedar apples" or ball-like galls on the cedar twigs push out yellowish-orange, gelatinous "horns" during rainy periods in the spring (Figs. 2 and 3). These horns consist of innumerable double-celled teliospores. The teliospores germinate on the surface of the horns, producing four basidiospores or sporidia from each cell. The sporidia may be carried by air currents to apple foliage and fruits where, given suitable moisture and temperature conditions, they will germinate and infect the tender tissues. Spots or lesions visible to the eye develop in 2 weeks. During the summer, aeciospores are produced on the undersides of the leaves beneath the spots above. These aeciospores, carried by winds to the cedars, may, under favorable conditions, infect the leaves of the cedar. In 2 years, usually, the resulting cankers or galls on the cedar develop to the point of teliospore production.

From a practical standpoint, the important feature of the life histories of these rust fungi is the fact that the spores produced on the apple, the aeciospores, cannot infect the apple. All infections on apple come from spores produced on the cedar.

Fig. 4.—Mature Apple Rust Lesions on a Wealthy Apple Leaf.

SYMPTOMS

More detailed knowledge of symptoms of the three rusts on both apple and cedar are of basic practical importance. On the apple leaves, lesions of the apple and hawthorn rusts are a conspicuous, bright orange color and appear much the same in size, altho actually the latter are somewhat smaller (Fig. 4). The cups producing aeciospores on the underside of an apple rust lesion are numerous and scattered, sometimes forming a ring near the margin; whereas those of a hawthorn rust lesion are few and are closely gathered in the centre.

FIG. 5.—APPLE RUST LESION ON ROME BEAUTY FRUIT.

On the apple fruits, the apple rust lesions are orange in color, vary in size from a quarter of an inch in diameter to include almost the whole cheek of the apple, and may be either sunken or raised, usually the latter (Fig. 5). The quince rust lesions are generally dark green in color and are usually decidedly sunken (Fig. 6). Unlike the apple rust fungus infections, which are relatively superficial, the lesions of the quince rust fungus involve all underlying tissues to the core. A further difference is found in the development of aecial cups. These are abundant in the case of lesions caused by the apple rust fungus but seldom are visible with quince rust lesions especially the more necrotic.

FIG. 6. — QUINCE RUST LESIONS ON A DELICIOUS APPLE.

(Photo by Thomas and Mills.)

On the cedar, the apple rust fungus and the hawthorn rust fungus are both characterized by the reddish brown "cedar apples" or ball-like galls on twigs which, when wet in the spring, extrude the gelatinous masses of teliospores. Galls of the apple rust (Fig. 2) are regularly rounded and their surfaces are covered with circular depressions, much like those on golf balls. Galls of the Hawthorn rust are irregular in shape and do not

FIG. 7.—QUINCE RUST GALLS ON RED CEDAR TWIGS.

show the regular arrangement of depressions. Also, the teliospore horns of the apple rust are long and tapering, while those of the hawthorn rust are short and wedge-shaped. The quince rust fungus on the cedar produces elongated, slightly swollen, deep red cankers on the twigs, limbs, and trunk (Fig. 7). During rainy periods, the teliospore masses break thru the bark in yellowish-orange sponge-like exudations. The three rust fungi may be found occurring together or separately on cedars. Galls of two, or even three, of them may be found on the same trees.

The apple rust fungus galls produce spores for but the one year. Galls of the other two species may produce spores for more than one year unless the affected host part dies.

SPORE PRODUCTION, SPORE DISSEMINATION, AND INFECTION

Generally, the galls of the apple rust fungus on the cedar begin the production of the teliospore-bearing horns by early May. The teliospores, with wetting, germinate immediately or shortly after their appearance, producing basidiospores. The minimum temperature for teliospore germination has been reported variously at 40° to 53° F, with an optimum range at 60° to 73°F. The basidiospores are discharged from the surface of the gelatinous masses with warm rains. Basidiospore discharges take place at an apparent minimum temperature of about 50° F, altho 40° F has been reported.

Galls soaked with rain for 30 minutes or even less may liberate basidiospores, but rains of 2 or 3 hours duration give heavier discharges. The spores are not liberated without lowered humidity, unless there is a protracted rain. Abundant sporulation requires 3 to 5 hours after the initial wetting period or 6 to 7 hours from air-dry galls. Gelatinization and drying of the spore horns, with accompanying basidiospore discharges, usually occur six to eight times during a season. A new cylinder of fresh spores is shoved out at the base of the spore horn as it protrudes with each rain. Cedar

apples are particularly active in discharging spores after a prolonged dry spell, but they appear to be temporarily exhausted after two or three closely successive periods of discharge. By the middle of June most of the spore horns have dropped from the galls.

The spores are dependent on wind of course for dispersal. The amount and distribution of basidiospore inoculum depends on a multiplicity of factors, *viz.*, the wetting periods, the situation of the cedars in relation to the apples, the infestation of galls on the cedars, wind direction and velocity, presence or absence of intervening barriers, such as woods, topography, and elevation. The spores may be carried several miles and remain viable for days even weeks.

The basidiospores germinate with satisfactory water requirements in 1 to 3 hours. Temperature range for basidiospore germination on the apple host is 47° to 85° F, with an optimum at 56° to 61° F. Little or no infection seems to occur with the early spring rains in the Hudson Valley which usually occur when the temperature averages between 40° and 45° F. The bi-hourly average temperature range of the wetting periods in the Valley during May and June, in which period infection takes place, is between 50° and 65° F. The more suitable infection periods do not occur with continuous wetting periods but with intermittent ones. There must be an intermission of a few hours between showers, or sufficient moisture after the spores are disseminated, for infection to take place.

Whether or not infection takes place depends on the susceptibility of the host at that time as well as suitable moisture and temperature. Only the very young fruits and the immature leaves not yet heavily cutinized can be penetrated by the basidiospore germ tubes. The period of susceptibility is longer with the more susceptible apple varieties.

The first macroscopic symptoms of infection are pale yellow discolorations on the green fruits or on the upper surfaces of the young leaves and are evident from 6 days to 2 weeks afterward. The foliage of trees in poor health is not only longer in showing symptoms but has fewer and smaller lesions or rust spots. The fewer the lesions to the leaf, the larger. Fewer lesions per leaf are required to defoliate weakened trees than vigorous trees.

About 60 days elapse from the time of the first visible symptoms to the time when the lesions on the apple produce aeciospores to re-infect the red cedar. Provided suitable rain periods and normal temperatures prevail, cedars will become infected in July or August.

Aeciospores blow to and inoculate the cedars thruout the remainder of the growing season. Drouth and high temperatures may kill out infections on the cedars in the early stages. The resulting galls are not noticed for almost a year later. In the Hudson Valley 2 years are required for the maturation of the galls on the cedars, with the liberation of more basidiospores to infect the apple.

The cedars vary in resistance to the apple rust fungus and consequently not all trees are infected. Trees that are heavily infected year after year tend to become resistant and the galls are very small. These weather and resistance factors are no doubt responsible for the fact that there is not a heavy incidence of cedar-apple rust every season and that the rust seems to run in cycles.

In spore production, spore dissemination, and infection, the hawthorn rust fungus differs but slightly from the apple rust fungus. With the hawthorn rust fungus, the spore horns once fully expanded seem incapable of drying down to their previous size or shape. In the case of a given single gall, the basidiospores are discharged for only one period of 2 or 3 days while the gelatinous mass is drying.

With the quince rust fungus, the teliospores in the gelatinous masses extruded from the galls on the cedar may not be mature enough to discharge basidiospores for 1 to 3 weeks after breaking thru the bark. They are generally ready to sporulate however, during the period of apple fruit susceptibility, that is, from the time the flower clusters begin to unfold to about the time the petals are mostly off. For all practical purposes, the danger from fruit infection with either the quince rust fungus or the apple rust fungus is over within 10 days or so after petal fall. Since the period of host susceptibility is so short the quince rust is severe on apple only in occasional years when wetting periods and basidiospore dissemination coincide with with the susceptible period of the apple.

So far as the apple host is concerned, spore germination, temperature relationships, spore dissemination, the time and conditions required for infection, and the appearance of symptoms are much the same for the quince rust fungus as for the apple rust fungus. The aeciospores of the quince rust on the apple fruits are mature and ready for release early in June.

ORCHARD TRIALS OF SPRAY MATERIALS

METHODS

SELECTION OF PLATS

Experimental plats were located in situations where cedar-apple rust had been severe in previous seasons. The blocks of trees selected were as uniform as possible in size, condition, and lay of land. The vigor of the trees in the more critical set-ups had been somewhat impaired by repeated incidences of rust during the previous years.

The unequal distribution of inoculum presents a big problem in conducting field tests for the control of apple rust and every effort was made to minimize this probable source of error. As far as possible single row plats were used and these were laid out to run at right angles to the infected cedars so that there would be comparable trees for each material tested. This layout was further augmented by duplications of plats, numerous untreated trees, and several omission trees at each spray application.

SPRAY MATERIALS

Koppers flotation sulfur paste.—This material was predominantly of the thylox grade, containing about 40 per cent sulfur. It is manufactured by the White Tar Company of New Jersey, Inc., Kearny, N. J.

Koppers dry wettable flotation sulfur.—This is the flotation sulfur paste described above dried and pulverized. It contained about 85 per cent sulfur. This product was also obtained from the White Tar Company of New Jersey, Inc., Kearny, N. J.

Camden flotation sulfur paste.—This wettable flotation sulfur is of the ferrox type. It was guaranteed to contain 35 per cent sulfur, with iron-oxide added to improve sticking properties. The Camden Coke Plant, Camden, N. J., manufactures this product.

Mike.—This product is a wettable sulfur, containing 95 per cent actual sulfur. It is made by the Dow Chemical Company, Midland, Mich. [The above four proprietary sulfur materials are in a class having particle sizes of 5 microns (1/2,500th inch) or less.]

Magnetic-Spray.—This material is a wettable sulfur containing about 98.5 per cent 325-mesh refined sulfur, with particle size ranging from about 14 to 44 microns. It is prepared by the National Sulphur Company, Inc., New York, N. Y.

Mulsoid.—This material is a crude ground sulfur of about 95 per cent actual sulfur, of which 98 to 100 per cent passes thru a 325-mesh screen (mesh openings 44 microns). It is made by the Sherwin-Williams Co., Cleveland, Ohio.

Kolofog.—Technically known as bentonite-sulfur, Kolofog is prepared by fusing sulfur into bentonite with which it has been previously blended. It contains from 30 to 40 per cent sulfur, with apparently highly colloidal properties. It is manufactured by the Niagara Sprayer and Chemical Co., Inc., Middleport, N. Y.

Catalytic sulfur.—This material is 325-mesh wettable sulfur, containing about 80 per cent actual sulfur, developed for use in combination with lime-sulfur solution. It differs from all other wettable sulfurs in its property of catalyzing the normal breakdown of lime-sulfur solution. That used in these trials was supplied by the Freeport Sulphur Company, New York, N. Y.

Lime-sulfur.—The standard, commercial liquid concentrate testing 32° Baume was used.

Coposil.—This proprietary copper fungicide is basically copper-ammonium silicate, containing about 15 per cent metallic copper and 25 per cent bentonite. It is manufactured by the California Spray-Chemical Corporation, New York, N. Y.

Z–O.—This product is a proprietary copper fungicide, synthetic copper zeolite, containing approximately 25 per cent metallic copper in combination with ingredients which supposedly render it non-hygroscopic and non-caustic. It is prepared by the Nichols Copper Company, New York, N. Y.

Orthol-K Medium and Orthol-K Ready Mix.—These materials are proprietary summer oils prepared by the California Spray-Chemical Corporation, New York, N. Y.

Lime.—High-calcium superfine spray lime, 325-mesh, prepared by the Whiterock Quarries, Bellefonte, Pa., was used in these tests.

Arsenate of lead.—The Corona Brand of lead arsenate, without spreader, prepared by the Corona Chemical Division of the Pittsburgh Plate Glass Company, Milwaukee, Wis., was used as the insecticide accompanying the fungicide in all the apple rust sprays.

APPLICATION OF SPRAYS

The spray materials were prepared in the tank according to standard recommendations. A spray gun with a 20-gallon per minute delivery at 400 to 600 pounds pressure was used in all of the experiments. The trees were covered as thoroly and evenly as possible and at the same time drenching was avoided. Every effort was made to apply the materials on a comparable basis. The object was to have the foliage protected as much as possible before rains. Treatments were applied at intervals ranging from 4 to 11 days, usually 6 to 9 days with an average of about 8, depending on the rate of apple growth.

RECORDING DATA

Unless otherwise stated, the data given in the table deal with individual infection periods.

The trees upon which counts were made were selected as representative in regard to condition, quantity of fruit (this is a factor in the amount of infection), and location for cedar-apple rust. Foliage infection was taken as the criterion of control since the amount of fruit infection was comparatively small and relatively uncertain due to the shortness of the period of susceptibility.

Counts were made from the terminals at random.

The data are averaged on the infected terminals only; for altho the percentages of uninfected twigs appear significant as recorded in the table, theoretically it would seem that if a high percentage of terminals on a tree were infected, all terminals on that tree should have been infected. Lack of uniform growth of all terminals on all parts of the tree is a better explanation for such occurrences rather than differences in effectiveness of materials. Consequently, attention was concentrated on terminals of uniform growth or vigor, as it was considered that this would be the more accurate record.

While in many blocks a record was made for each infected leaf on a given terminal, the most heavily infected leaf on each terminal is regarded as the best criterion of control. This conclusion seemed justified in that the infection periods occurred for the most part when terminal growth was nearing completion.

The data are considered as representing the general trend of control and are comparative, but do not in every case present the complete picture of the results. It was not uncommon to find considerably heavier infection on the prevailing windward side of both treated and check trees. As would be expected with the unequal distribution of inoculum, particularly close to cedars, the line of demarcation between heavy and light infection was very pronounced, sometimes occurring between two adjacent rows of apple trees.

TYPICAL SEASONAL DEVELOPMENT OF APPLE RUST

Apple rust infection may take place in the Hudson Valley over a period extending from the end of April to the latter part of June. Spore discharges from the cedar galls can take place when the telial horns are less than ¼ inch in length. Within two or three days of May 1 in each of the years 1930 to 1936, inclusive, cedar rust galls, when wetted, have protruded telial horns ½ inch. In some years, tho,

there has been as much as 10 days variation in actual spore development previous to this date. From galls brought into the laboratory, basidiospore discharges were first obtained on April 25 in 1931, April 27 in 1932, April 30 in 1934, April 25 in 1935, and April 17 in 1936.

The first apple rust infection was observed on May 15 in 1930, May 26 in 1931, May 18 in 1932, May 12 in 1933, May 18 in 1934, May 16 in 1935, and May 21 in 1936. Heavy foliage infection, however, was not apparent in any of these years before the last week of May.

Apple fruit infection has taken place as early as the first week in May and as late as the first week June. Heaviest fruit infection has been observed to occur with the rains in the early stages of fruit development. June rains have caused little commercial loss from fruit infection.

The number of spore discharges from the cedar galls naturally has varied with the number and duration of rain periods. The spores have all been discharged in two or three rains, when the rains did not occur until June, but in other seasons have been liberated many times when the rains were frequent in the earlier stages of spore horn development.

To illustrate conditions more specifically and to give a more consecutive review of seasonal developments than may be readily obtained from the conditions reported under series 1 to 11, pages 20 to 28, exact records of the past two seasons, 1935 and 1936, are given herewith. Naturally, rainfall, length of wetting periods, and temperatures vary with different districts in the Valley and, consequently, spore production, host development, and infection vary somewhat. The figures given represent ranges and averages.

SEASON OF 1935

On April 4, 1935, in the southern part of the Valley, the telial horns on the cedar galls protruded about 1/16 to 1/8 inch, while in in the center and northern sections the epidermis of the galls was unbroken. By April 15 telial horns could be found in any of the infested red cedar blocks anywhere in the whole area. On April 25, when galls were soaked 1 hour in water, they shot viable basidiospores profusely. Apple bud development at this time was in a full delayed-dormant stage, and almost an early pink stage in some orchards.

The first natural spore discharge came with a wetting period of 12 hours at 52° F on April 29. With a shower on May 2, telial horns

were out 1/2 inch. There were wetting periods of about 8 to 20 hours at a 40° bi-hourly average temperature on May 3 and 4, of 14 to 18 hours at 47° on May 5 and 6, and of 22 to 24 hours at 51° on May 6 and 7. Rust lesions of apple leaves first showed on May 16, but the amount of infection was insignificant.

Apple bloom was about completed May 23, except in the more backward locations. The next, and the first general, infection followed wetting periods of about 19 to 21 hours at a 64° bi-hourly average temperature on June 4 and 5, 6 to 7 hours at 58° on June 6, and 23 to 30 hours at 58° on June 8 and 9. The foliage infection showed up on June 16. The remaining infections of the season occurred with wetting periods of about 23 to 38 hours at 56° average temperatures on June 17 to 19, 15 to 18 hours at 62° on June 19 and 20, and 19 hours at 65° on June 21 and 22. Foliage infection from these periods was evident July 10. The last spore discharge came with a heavy shower June 27.

SEASON OF 1936

The season of 1936 was over a week earlier than normal. The telial horns on the cedar galls protruded 1/5 inch on April 17 and discharged viable spores profusely. April 28, at Poughkeepsie, a wetting period of 12 hours at an average temperature of 52° F gave the first possible apple rust infection period. At this time apple fruit bud clusters were about ready to separate.

Probably the first serious cedar rust infection period came in the southern end of the Valley with the rain of May 3 to 4, at which time the telial horns were out 1/2 to 1 inch. Three closely consecutive wetting periods of about 7, 6, and 3 hours, with respective average temperatures of 63°, 54°, and 50° F, occurred on 2 days, May 3 and 4. The apple rust that showed up about May 21 probably resulted from these wetting periods, altho the telial horns protruded during a wetting period of 6 hours at 50° F on May 7. Heavy fruit infection occurred in the lower Valley from these rains in early May.

Thruout the Valley, high temperatures caused tremendous growth during bloom. Petal fall, in general, was completed May 11.

The first important apple rust infection period in the central section occurred with a rain of 14 hours at 52° F on May 13 and 14. Rust infections on apple foliage showed up on June 1. Scattered wetting periods of at least 9, 5, and 6 hours, with respective average temperatures of 63°, 64°, and 58° F, occurred May 18 and 19, but no apple rust infection followed.

Foliage growth was 2 to 5 weeks ahead of normal May 27. On this date, telial horns on the cedar galls were extended with a wetting period of 7 to 11 hours, having an average temperature of 66° to 70° F. but apparently no infection took place.

A wetting period of 13 to 15 hours, with an average temperature of 58° F, occurred June 3. Lesions on apple foliage appeared June 16 to 25. General wetting periods of 13 to 15 hours at 66° occurred June 11 and 12 and of 35 to 60 hours at 63° on June 12 or 13 to 15. Infections from these wetting periods were evident about July 3. All danger from apple rust infection was passed by June 20.

RESULTS OF EXPERIMENTS

Regional variations in conditions and the uncertainty of obtaining infection periods made it essential to conduct spraying experiments in a number of orchards each season. Consequently, a separate presentation of both conditions and results is made for each series of experiments.

Thruout both seasons of 1935 and 1936, close records were kept in each experimental block of rainfall and wetting periods, of temperatures, of apple development, and of rust infection and incubation periods on the apple. These and other factors having an important bearing on the interpretation of the results, such as the general condition of the trees, layout of plants, and application of sprays, are given with the results. In all instances, galls on nearby cedars were in ideal condition to produce spores, provided the requisite moisture and temperature conditions prevailed.

For a tabulation of the results by series see Table 1.

Series 1, 1935, Rome Beauty Orchard of John Shuart, Suffern, N. Y.— Vigor in this mature orchard was poor to average. Incidence of apple rust had been severe in previous years. There were some rust-infected cedars in the woods immediately bordering the orchard, but the greater portion of the inoculum seemed to come from cedars some distance in the woods, as shown by the angle of heaviest incidence of apple rust in the block.

The fruit clusters were in the calyx stage May 20. Terminal growth of twigs was completed about June 3.

The treatments, Mulsoid sulfur 6–100, Koppers dry wettable flotation sulfur 5-100, Camden flotation sulfur paste 8–100, and Kolofog 6-100, were applied on June 3 and again on June 17.

A wetting period of 21 hours with 0.28 inch of rain at an average temperature of 64°, occurred on June 4 and 5; a second of 6 hours

with 0.17 inch of rain at 63° occurred on June 6; and a third of 23 hours with 1.0 inch of rain at 58° occurred on June 8 and 9. Two other wetting periods of 38 and 18 hours with 1.15 and 0.26 inches of rain and average temperatures of 57° and 60° F respectively, came on June 17 to 19 and June 19 and 20.

The omission trees for the June 3 application showed that the infection was due to the wetting periods that began June 4. The foliage infection appeared June 16. Because of lack of susceptible new apple foliage growth, no infection followed the rains of June 17 to 20. There was no fruit infection of commercial importance.

The sprays of Camden flotation sulfur paste and Kolofog gave perfect control under the conditions of this series where the unsprayed trees had an average of 169.2 lesions on the most heavily infected leaf average per infected terminal (Fig. 8) or an average of 88.2 lesions per infected leaf. The Koppers dry wettable flotation sulfur may be said to have given commercial control, but was not as effective as the paste form of flotation sulfur. The Mulsoid sulfur, which had been substituted for lime-sulfur because of serious foliage injury earlier, did not give significant control.

This block illustrates the tremendous variability in amount of rust spore inoculum within comparatively short distances. Check tree 1 in row 2, check tree 2 in row 6, and check tree 3 in row 9 had, respectively, 169.2, 33.0, and 4.4 rust lesions on the most heavily infected leaf averaged per infected terminal. Koppers dry wettable gave complete control where the incidence of apple rust was comparable with that of check tree 2. The amount of rust on the Mulsoid treatments paralleled those of the comparable checks in all three instances.

Series 2, 1935, Rome Beauty Orchard of John Shuart, Suffern, N. Y. – The trees in this block were younger, about 12 years old, and were more vigorous than those in series 1. The plats were laid out beside heavily rust-infected cedars.

Koppers dry wettable flotation sulfur 5-100, with and without Orthol-K medium summer oil (1- quart in 100 gallons), and Camden flotation sulfur paste 8-100, were applied. Rain periods and application of sprays were the same as in series 1.

Camden paste gave complete control. Koppers dry wettable flotation sulfur gave commercial control but was not entirely effective. The addition of the Orthol-K medium summer oil to the Koppers dry wettable sulfur as a sticker effected perfect control.

TABLE 1.—RESULTS OF SPRAY TRIALS OF CERTAIN SULFUR AND COPPER MATERIALS FOR CONTROL OF APPLE RUST IN THE HUDSON VALLEY IN 1935 AND 1936.

Treatment[a]	No. of trees examined	No. of terminals examined	Percentage of terminals infected	Percentage of leaves infected with 10 or more lesions	Average results on infected terminals: No. of leaves infected	No. of lesions per leaf	No. of lesions on heaviest infected leaf
Ser. 1[b], 1935, Rome Beauty (John Shuart)							
Untreated (1)	1	43	100.0	79.1	4.7	88.2	**169.2**
Untreated (2)	1	137	100.0	—	—	—	**33.0**
Untreated (3)	1	144	86.1	—	—	—	**4.4**
Mulsoid 6–100 (1)	4	191	100.0	70.3	4.3	56.2	**128.8**
Mulsoid 6–100 (2)	2	601	93.2	—	—	—	**14.4**
Mulsoid 6 100 (3)	2	156	—	—	—	—	**4.3**
Koppers dry wettable 5–100 (1)	3	1,075	69.9	9.7	2.1	5.9	**6.8**
Koppers dry wettable 5–100 (2)	2	—[c]	0.0	0.0	0.0	0.0	**0.0**
Camden paste 8–100 (1)	5	—[c]	0.0	0.0	0.0	0.0	**0.0**
Kolofog 6–100 (1)	5	—[c]	0.0	0.0	0.0	0.0	**0.0**
Ser. 2[d], 1935, Rome Beauty (John Shuart)							
Untreated	1	285	100.0	80.1	4.5	104.0	**187.6**
Koppers dry wettable 5–100	4	341	69.8	—	—	—	**3.7**
Koppers dry wettable 5–100 & oil 1 qt.	4	—[c]	0.0	0.0	0.0	0.0	**0.0**
Camden paste 8–100	4	—[c]	0.0	0.0	0.0	0.0	**0.0**

Ser. 3[d], 1935, Rome Beauty (S. Hubbard)							
Untreated	2	374	100.0	15.1	4.6	6.3	**11.8**
Magnetic-Spray 6–100	3	804	80.0	2.9	2.0	2.4	**3.1**
Koppers dry wettable 5–100	3	661	82.7	1.5	2.2	2.3	**3.0**
Koppers dry wettable 5–100 & oil 1 qt	3	914	67.7	1.9	1.9	2.2	**2.5**
Ser. 4[bd], 1935, Winter Banana (H. Gage)							
Untreated (1)	1	199	100.0	58.2	4.2	22.8	**49.9**
Untreated (2)	1	140	100.0	59.8	3.5	20.5	**41.4**
Magnetic-Spray 6–100 (1)	2	572	88.9	11.7	2.1	4.6	**7.1**
Magnetic-Spray omitted June 4 (1)	1	185	100.0	62.4	4.3	20.6	**40.3**
Koppers dry wettable 5-100 (1)	2	1,143	91.5	21.9	2.5	6.4	**10.2**
Koppers dry wettable 5–100 & oil 1 qt (1)	2	735	77.6	4.8	2.1	3.6	**4.9**
Koppers dry wettable 5–100 (2)	2	1,162	95.3	32.8	2.6	8.8	**14.9**
Koppers dry wettable 5–100 & oil 1 qt (2)	2	881	69.7	15.6	2.1	5.3	**7.8**
Ser. 5[ef], 1936, Jonathan (Mrs. R. Teator)							
Untreated (1st row from cedars)	3	212	100.0	—	—	—	**30.5**
Untreated (3rd row from cedars)	5	352	100.0	—	—	—	**14.4**
Sprays omitted May 13	6	393	100.0	—	—	—	**15.2**
Camden paste 6–100	6	—[c]	0.0	—	—	—	**0.0**
Magnetic-Spray 6–100	6	—[c]	0.0	—	—	—	**0.0**
Mulsoid 6–100	5	—[c]	0.0	—	—	—	**0.0**
Kolofog 6 100	8	—[c]	0.0	—	—	—	**0.0**
Mike 3 & 5-100	5	—[c]	0.0	—	—	—	**0.0**

[a]Abbreviations are as follows: Camden paste = Camden flotation sulfur paste; Bordo = Bordeaux mixture; Koppers paste = Koppers flotation sulfur paste; L-S = lime-sulfur. The concentrations are expressed as so many pounds in the given number of gallons of water. Where three figures are present in the formulae, the second refers to pounds of hydrated lime. Arsenate of lead 3–100 was used in all of the sprays except those applied during bloom.

[b]The numbers after the treatments correspond with those after the untreated trees indicating which unsprayed trees were nearest to the sprayed ones.

[c]Actual counts were not made since the foliage was clean.

[d]Orthol-K medium summer oil was used 1 quart in 100 gallons. The infection period began at the time the spray was applied.

[e]Sprays omitted refers to trees left in the treated rows without spray for this one application.

[f]The block in Ser. 6 is the same as in Ser. 5. A road separated the trees from the cedars.

TABLE 1.—*Concluded.*

Treatment[a]	No. of trees examined	No. of terminals examined	Percentage of terminals infected	Percentage of leaves infected with 10 or more lesions	Average results on infected terminals: No. of leaves infected	Average results on infected terminals: No. of lesions per leaf	Average results on infected terminals: No. of lesions on heaviest infected leaf
Ser. [ef] 6, 1936, Jonathan (Mrs. R. Teator)							
Sprays omitted May 29	6	603	87.7	—	—	—	24.3
Average of treated trees	17	1,714	67.1	—	—	—	9.2
Ser. 7[e], 1936, Rome Beauty (S. Hubbard)							
Untreated	2	258	100.0	50.4	5.1	13.3	28.7
Koppers paste 6–100	4	613	52.2	0.4	2.2	1.2	1.8
Koppers paste omitted May 29	3	375	97.9	16.1	3.1	5.1	9.1
Lime-sulfur 1–100	2	478	65.7	0.8	2.0	1.6	2.3
CA 2–3- 100	2	186	100.0	57.2	4.8	13.9	26.9
CS 2–3–100	2	369	90.2	1.7	2.0	2.6	3.3
Ser. 8, 1936, Wealthy (H. Morgenthau)							
Untreated	6	406	100.0	35.9	3.2	8.7	14.9
Camden paste 3–100	2	181	87.3	2.1	2.1	2.7	3.8
Camden paste 6–100	4	451	76.5	0.3	1.9	1.9	2.1
Camden paste 9–100	2	271	68.3	0.8	2.0	1.7	2.7
Lime-sulfur 1–100	8	593	78.4	0.4	2.0	2.0	2.8
Ser. 9, 1936, Wealthy (H. Morgenthau)							
Untreated	7	524	100.0	40.0	6.6	9.8	20.0
Camden paste 3 100	5	390	96.4	2.5	3.7	2.6	4.4
Camden paste 6–100	7	632	87.9	2.8	2.7	2.7	4.3
Camden paste 9–100	5	559	78.5	1.3	2.8	2.1	3.1
Lime-sulfur 1 100	7	564	91.0	6.0	3.7	3.4	5.9
Untreated (fruit light)	3	245	100.0	10.0	4.2	5.9	9.6
Untreated (fruit heavy)	3	199	100.0	38.3	7.3	9.0	20.6

Ser. 10[b][e], 1936, Rome Beauty (H. Morgenthau)							
Untreated (1)	1	68	——	59.7	5.7	18.6	**40.7**
Untreated (2)	1	77	——	56.5	5.3	17.0	**36.3**
Untreated (3)	1	64	——	51.0	3.8	11.4	**19.9**
Untreated (4)	1	78	——	61.2	4.4	15.8	**29.7**
Sprays omitted June 1	4	421	——	38.8	3.4	9.2	**16.0**
Bordo 2–3–100 (1)	6	938	——	0.9	1.6	2.0	**2.1**
Kolofog 6–100 (2)	5	354	——	3.4	1.5	2.9	**3.5**
Camden paste 6–100 (2–3)	4	174	——	2.3	1.5	2.9	**3.0**
Z-O 1–1½–100 (3)	4	280	——	19.4	3.3	6.2	**9.9**
Coposil 2–3–100 (4)	5	329	——	11.7	2.8	5.1	**7.3**
Ser. 11[b], 1936, Rome Beauty (John Shuart)							
Untreated (1)	1	275	94.4	——	——	——	**21.4**
Untreated (2)	1	127	94.1	——	——	——	**22.7**
Untreated (3)	1	185	76.2	——	——	——	**14.1**
Untreated (4)	1	199	97.5	——	——	——	**8.5**
Untreated (mature tree) (5)	1	150	67.3	——	——	——	**5.2**
Untreated (young tree) (6)	2	35	100.0	——	——	——	**68.0**
Koppers paste 6–100 (1)	3	827	42.9	——	——	——	**6.9**
Koppers paste 6–100 (4)	3	——[c]	——	——	——	——	Trace
Magnetic-Spray 6–100 (2)	2	265	51.3	——	——	——	**3.4**
Mulsoid 6–100 (2–3)	2	333	47.4	——	——	——	**3.2**
Kolofog 6–100 (3)	2	291	32.1	——	——	——	**3.1**
L-S 1–100 & catalytic sulfur 4–100 (5)	2	——[c]	0.0	——	——	——	**0.0**

[a]Abbreviations are as follows: Camden paste = Camden flotation sulfur paste; Bordo = Bordeaux mixture; Koppers paste = Koppers flotation sulfur paste; L-S = lime-sulfur. The concentrations are expressed as so many pounds in the given number of gallons of water. Where three figures are present in the formulae, the second refers to pounds of hydrated lime. Arsenate of lead 3–100 was used in all of the sprays except those applied during bloom.

[b]The numbers after the treatments correspond with those after the untreated trees indicating which unsprayed trees were nearest to the sprayed ones.

[c]Actual counts were not made since the foliage was clean.

[d]Orthol-K medium summer oil was used 1 quart in 100 gallons. The infection period began at the time the spray was applied.

[e]Sprays omitted reters to trees left in the treated rows without spray for this one application.

[f]The block in Ser. 6 is the same as in Ser. 5. A road separated the trees from the cedars.

FIG. 8.—APPLE RUST LESIONS ON AN INFECTED ROME BEAUTY TERMINAL.

The arrow points to the most heavily infected leaf, which was considered the best criterion of control. The lesions were counted on the most heavily infected leaf on each of the infected terminals and averaged to obtain the index of infection.

Series 3, 1935, Rome Beauty Orchard of S. Hubbard, Poughkeepsie, N. Y.—Trees here were mature and in good vigor. The source of inoculum was from heavily infected cedars over 80 rods away and not directly in the line of prevailing winds.

The apple fruit clusters were from 50 to 80 per cent open on May 14. Growth of foliage on terminals continued until the third week of June.

Wetting periods of 19, 7, and 30 hours with 0.32, a trace, and 1.44 inches of rain and average temperatures of 64°, 58°, and 58° F, occurred on June 4 and 5, 6, and 8 and 9, respectively. Wetting periods of 12, 11, 15, and 19 hours with a rainfall of 0.6, a trace, 0.27 and

0.29 inch and average temperatures of 55°, 56°, 63°, and 65° F, took place June 17 and 18, 18 and 19, 19 and 20 and 21 and 22, respectively.

The treatments included Magnetic-Spray 6–100 and Koppers dry wettable sulfur 5–100 (with and without Orthol-K medium summer oil, 1 quart to 100 gallons), and were applied June 4 and 13. Sufficient growth of terminals took place after the applications of June 13 so that two to three leaves on each terminal were unprotected during the rains that began on June 17.

Foliage infections showed up from the two general wetting periods on June 16 and July 10, respectively.

Both Magnetic-Spray and Koppers dry wettable sulfur were effective. What infection occurred on the sprayed trees was due to unprotected foliage, as is shown by the difference in number of infected leaves per twig compared to the untreated trees. Further, no apple rust was apparent on the sprayed trees at the time first infection was recorded on the unsprayed trees. Conditions were not such that the use of the summer soil as an adhesive agent showed any great reduction in the amount of infection, except perhaps that fewer terminals were infected.

Series 4, 1935, Winter Banana Orchard of H. Gage, Rhinebeck, N. Y.— The mature trees in this series were in average vigor. There were infected cedars at both ends of the apple block but none closer than 40 rods. Apple bloom was over and the petals were off by May 21. Some terminals had two unprotected leaves for the rains of June 17 and later.

Applications of Magnetic-Spray 6–100 and Koppers dry wettable flotation sulfur 5–100 (with and without Orthol-K medium summer oil, 1 quart to 100 gallons water) were made June 4 and 12. Wetting periods were the same as for series 3. The major infection period began on June 4 (as indicated by the omission tree), while sprays were being put on. Foliage infection was apparent June 16 and 24 and July 12. There was about 4 per cent fruit infection.

In this series, the sprays were not too effective in rust control. This was not so much the fault of the materials as of weather conditions. None of the treatments in the applications of June 4 had time to dry before the first infection period began. Some infection took place during the second infection period because of unprotected new growth.

The data show that the degree of control was proportionate to the concentration of inoculum, as was evident in series 1.

Magnetic-Spray was comparable to Koppers dry wettable sulfur, altho the data slightly favor the former material. On trees growing side by side, Koppers dry wettable sulfur treatment averaged 7.9 lesions as compared with 7.1 lesions for the Magnetic-Spray on the most heavily infected leaf averaged per infected terminal.

Trees thruout the block sprayed with Koppers dry wettable sulfur varied from 7.9 to 18 lesions on the most heavily infected leaf averaged per infected twig. The foliage was more heavily infected on the windward side. The results show that the use of oil, 1 quart in 100 gallons, increased the effectiveness of the Koppers dry wettable sulfur approximately 50 per cent. The foliage of the trees treated with the oil combination was virtually clean as the lesions on the first infection period appeared. Sulfur analyses indicate that the oil increased the adhesiveness of the sulfur about 30 per cent.

Series 5, 1936, Jonathan Orchard of Mrs. R. Teator, Upper Red Hook, N. Y.—Trees were in average vigor. Incidence of apple rust was severe in previous years. Infected cedars ran across the end of the block. Apple blossoms began opening on May 6.

Camden flotation sulfur paste 6–100, Magnetic-Spray 6-100, Mulsoid sulfur 6–100, Kolofog 6–100, and Mike sulfur 3 and 5-100 were applied May 13 (the calyx spray). The treatments were put on single row plats, running up to the cedars, and were duplicated in two blocks. Orthol-K Ready Mix, 1 per cent, for red mite control, was used with all the materials.

A wetting period of 14 hours with a rainfall 0.5 inch and of an average temperature of 52° F occurred May 13 to 14. The omission trees demonstrated that infection took place during this rain period. Apple rust lesions were in evidence about June 1 on the ninth, tenth, and eleventh terminal leaves. There was no fruit infection.

In this block, again, unevenness of rust inoculum was decidedly apparent. Disease incidence on check trees in the third cross row, 100 to 120 feet from the cedars, was slightly less than half that on check trees in the first cross row next to the cedars. The untreated trees ranged from an average of 11.7 to 33.3 lesions on the heaviest infected leaf per twig. The average on the most heavily infected sides of the check trees ran as high as 39.9 lesions. On terminals on the omission trees, the average number of lesions ranged from 3.9 to 28.3 per heaviest infected leaf.

All the treatments gave complete control. Differences between materials, all sulfurs, probably were offset by the increased adhesive-

ness obtained thru the use of the summer oil.

Some foliage injury followed the use of oil and sulfur in combination, injury being more severe on the weaker trees. When rains followed immediately after applications, injury was more serious than when good drying conditions prevailed. Kolofog caused the least injury, a trace, and Mike sulfur the most. This difference might be attributed either to differences in amount of actual sulfur applied to the trees or to the bentonite in the Kolofog.

Series 6, 1936, Jonathan Orchard of Mrs. R. Teator, Upper Red Hook, N. Y.—This series comprised the same applications on the same trees as in series 5, but covers a later infection period. The trees were sprayed May 29. A wetting period of 15 hours with a rainfall of 0.31 inch and an average temperature of 58° F followed on June 3 and 4.

Omission trees showed that infection took place at this time. Lesions on the leaves were prominent on June 25. There was no fruit infection.

These data are presented to show that sprays may not be effective against apple rust 5 days after application, even when host development is comparatively slow at the end of the growing season. Since there was no significant difference between the treatments, only a summary of counts is given. On the treated trees, the average number of lesions on the most heavily infected leaves per infected terminal ranged from 0 to 19.2, with an average of 9.2. This compared with an average of 24.3 lesions on the unsprayed trees.

Series 7, 1936, Rome Beauty Orchard of S. Hubbard, Poughkeepsie, N. Y.—The mature trees were in good vigor and were about 40 rods to the windward side of the cedars. Bloom began on May 5 and the petals were off by May 12. Growth was about complete June 9.

Koppers flotation sulfur paste 6–100, lime-sulfur 1–100, and two experimental materials, CA 2–3–100 and CS 2–3–100, were applied May 29.

A wetting period of 15 hours with a rainfall of 0.31 inch and an average temperature of 58° F occurred June 3 and 4. Omission trees indicated that infection took place in this early June rain period. Foliage lesions appeared about June 16. There was no fruit infection.

Koppers paste and lime-sulfur were quite effective in this series, and results with the CS material did not differ from them significantly except in the greater number of terminals infected. The CA material was wholly ineffective at the concentration used.

Later treatments applied on this block June 9 gave but slight protection against one or both of the infection periods of 15 hours June 12 and of about 35 hours June 13 to 14, that is, on trees that had put out new growth in the interim. Some trees, tho, that had made no appreciable new growth, remained rust-free.

Series 8, 1936, Wealthy Orchard of H. Morgenthau, Wicopee, N. Y.—The trees in this orchard were in good vigor and most of them carried a heavy load of fruit. Infected cedars were prevalent in the entire countryside round about, and the source of inoculum was indefinite. The apple trees were in full bloom and petals were dropping May 7.

Camden flotation sulfur paste 3, 6, and 9–100 and lime-sulfur 1–100 were applied June 1.

A wetting period of 15 hours with a rainfall of 0.31 inch and an average temperature of 58° F occurred June 3 and 4. Omission trees indicated that infection took place during this wetting period. Foliage lesions appeared about June 16. There was some fruit infection.

The unsprayed trees, distributed thru the block, indicated that the rust spore inoculum was evenly distributed. Both Camden paste and lime-sulfur were effective against apple rust under the conditions prevailing in this orchard. For all practical purposes, Camden paste at 3–100 was as effective as at 6 or 9–100. While the higher concentrations achieved slightly better control, this trend was insignificant as compared to the amount of infection that evidently took place on the unprotected foliage grown in the 2- to 3-day interval between the spray applications and the infection period. In other words, coverage was more important than concentration of material in this experiment.

Series 9, 1936, Wealthy Orchard of H. Morgenthau, Wicopee, N. Y.—The apple block in this series was the same as in series 8. Terminal growth had nearly stopped in mid-June. The spray treatments of June 1 were repeated June 9. Two wetting periods of 15 and 35 hours with respective rainfalls of 0.35 and 2.12 inches and average temperatures of 58° and 66° F took place June 11 and 12 and June 13 to 15. The foliage lesions showed up about July 3.

The counts include infections occurring during the previous period (June 3 and 4) of series 8. The trends relative to materials and concentrations were the same in this series as in series 8. The additional infection periods increased the incidence of apple rust only slightly on the sprayed plats, even tho heavy rains came 2 to 6 days after the applications were made. This demonstrates that when growth is less

rapid, the sulfur materials may be relied on to protect the apple foliage against rust infection for a longer period of time than would be the case earlier in the season.

The point of greatest interest in this series was that the trees with but a light crop of fruit were somewhat resistant to rust infection on their leaves. Incidence of apple rust for the entire season was twice as heavy on the light-yielding untreated trees as on heavy-yielding untreated trees of the same age and growing under identical soil and cultural conditions.

Series 10, 1936, Rome Beauty Orchard of H. Morgenthau, Wicopee, N. Y.— The full-grown trees in this orchard were in good vigor but bore little or no fruit. Rust inoculum sources on cedars were numerous and general, but not nearby.

Bordeaux mixture 2–3–100, Kolofog 6–100, Camden flotation sulfur paste 6-100, Z-O 1-1½–100, and Coposil 2–3–100, were applied June 1 and June 9. The wetting and incubation periods were identical with those given for series 8 and 9. The data presented are from the infection period of June 3 to 4. This was ascertained from the omission trees of June 1.

In this experiment, bordeaux, Kolofog, and Camden paste all gave commercial control. The Z-O and Coposil Treatments were comparatively ineffective.

Adjusting the figures on disease incidence to compensate for variations in concentration of inoculum, as shown by infections on the unsprayed check trees, emphasizes the effectiveness of bordeaux and the lack of effectiveness of the other two copper materials. Thus, whereas bordeaux, Z-O, and Coposil had, respectively, an actual average of 2.1, 9.9, and 7.3 lesions on the most heavily infected leaf averaged per infected terminal, these figures give no consideration to the heavier infection on the bordeaux check (40.7 as against 19.9 and 29.7, respectively). On an adjusted basis, the average infection index becomes 2.1 for bordeaux, 20.2 for Z-O, and 10 for Coposil. The bordeaux gave some foliage injury, characterized by purplish discoloration.

Unlike series 9, the fungicides applied on this block June 9 did not give uniform rust protection from the infection periods of June 11 to 15. Trees that made no new terminal growth showed no additional infection, but about half of them had put out new and susceptible leaves after June 9 and before June 15.

Series 11, 1936, Rome Beauty Orchard of John Shuart, Suffern, N. Y.—

This block is the same as in series 1. Koppers flotation sulfur paste 6–100, Mulsoid sulfur 6 100, Kolofog 6–100, and lime-sulfur 1–100 plus catalytic sulfur 4–100, were applied June 2 and 11.

Wetting periods of 13, 13, and 60 hours with average temperatures of 58°, 66°, and 63° F occurred June 3 and 4, 11 and 12, and 12 to 15.

Apple rust in this series probably came from the wetting period of June 3 to 4. The data presented were taken June 24. Lesions from the later infection period in mid-June were observed in July on terminals that had evidently put out new growth between June 11 and 15. Heavy fruit infection observed on June 1 had taken place presumably during the first week of May.

The Koppers paste in this test, under moderate inoculum conditions, gave somewhat less control than the other materials. With slight inoculum, this material gave perfect control. The data for the lime-sulfur and catalytic sulfur combination are not necessarily significant, since there was either insufficient inoculum or the trees were too resistant for infection to take place. The lime-sulfur and catalytic sulfur mixture, however, is apparently an ideal spray with which to lay down a heavy residue on smooth foliage.

The factor of resistance due to lack of tree vigor was apparent in this block. In one instance, a mature untreated tree had an average of only 5.2 lesions on the most heavily infected leaf averaged per infected terminal, whereas some untreated young filler trees close by had an average of 68 lesions.

DISCUSSION

These orchard spray trials show that under most Hudson Valley conditions, at least, apple rust on foliage can be completely controlled by the use of fungicides. Perfect control, however, was obtained only when the spray applications immediately preceded the wetting periods that produced the infection (Ser. 1, 2, and 5). When 2 to 5 days elapsed between the dates of application of effective materials and infection periods, an average of about two young leaves per terminal was somewhat infected (Ser. 3, 7, 8, 9, and 10). In districts where rust is usually troublesome, however, an approximation of three to seven lesions per most heavily infected leaf per terminal in each infection period, such as was obtained with effective materials in most of the experimental series, may be considered good commercial control.

As is typical of most districts and of normal seasons, rust infections on apple fruits were not common in the experimental orchards, reaching a maximum of 4 per cent in series 4.

Of the proprietary materials, Camden flotation sulfur paste at dilutions of 6 or 8–100 (Ser. 1, 2, 5, 8, 9, and 10) and Kolofog at 6–100 (Ser. 1, 2, 5, 10, and 11) received the most extensive testing, and both gave consistently good results. The Camden paste even at 3-100 gave good control (Ser. 9). While this concentration was effective in this particular instance, representative of average apple rust conditions in the Hudson Valley, it might, however, prove ineffective under conditions of heavier rainfall and heavier spore discharges. In one test, Koppers flotation sulfur paste 6–100 appeared as effective as lime-sulfur at a 1-100 dilution (Ser. 7). This was equivalent to the results obtained with the other flotation sulfur, Camden paste 6 100 (Ser. 8 and 9). But in a third experiment (Ser. 11), the Koppers paste seemed a shade ineffective.

The dry form of wettable flotation sulfur (Koppers) at 5–100, while giving commercial control in all trials, was less effective than the paste form (Camden) at 8–100 when higher concentrations of inoculum were present (Ser. 1, 2, and 3). Adding Orthol-K Ready-Mix, a summer oil, to Koppers dry wettable at the rate of 1 quart in 100 gallons, gave a consistent improvement in rust control (Ser. 2, 3, and 4). The better control obtained with the inclusion of oil is attributed to increased adhesiveness of the spray. Sulfur analyses of sprayed apple leaves have shown that the addition of oil increased the sticking properties from 30 to 50 per cent.

Oil has usually been considered incompatible with sulfur for apple spraying. In these trials, however, no appreciable injury to apple foliage resulted when oil was used at the rate of 1 quart in 100 gallons (Ser. 2, 3, and 4). Where summer oil was used at the rate of 1 gallon in 100 gallons of sulfur spray, however, various degrees of injury followed (Ser. 5). Degree of injury varied with kind of sulfur spray material, with vigor of trees, and with drying conditions after application of sprays. (See series 5, page 24.)

Mulsoid sulfur 6 100 varied widely in effectiveness, regardless of the amount of inoculum (Ser. 1, 5, and 11). Magnetic-Spray 6–100, under the less severe of the tests, was as effective as the Koppers dry wettable sulfur 5 100 (Ser. 3 and 4) and Camden paste and Kolofog (Ser. 5 and 11). Mike sulfur 3 and 5–100 gave perfect control

(Ser. 5); however, in the only trial of this material, 1 per cent oil (Orthol-K Ready-Mix) was added for red mite and may have enhanced its effectiveness.

In apple rust control, lime-sulfur at 1–100 dilution was approximately equivalent to the flotation sulfur pastes at 6–100 (Ser. 7, 8, and 9).

Copper materials were tried in only one series, but under almost ideal apple rust test conditions (Ser. 10). Bordeaux mixture 2-3-100 gave good control. Coposil 2–3–100 and Z-O 1–1½–100, however, were relatively ineffective. The poor control obtained with Coposil and Z-O might have been due to any one or a combination of three factors, *viz.*, lack of toxicity to the fungus, use at too low concentrations, or lack of adhesiveness. Copper analyses of sprayed leaves has shown, however, that, even when applied on an equivalent copper basis, these two materials deposited only 67 per cent as much copper residue as bordeaux and after the first inch and a half of rain gave but 37 per cent as much protection.

It is obvious from the above discussion that both sulfur and copper fungicides are effective against apple rust. As regards materials, the salient feature in the results of these tests seems to be that the consistently effective sprays have been those that were most adhesive; in other words, those that deposited the heaviest and longest-lasting residues. On the basis of its action at the 1 to 100 concentration, lime-sulfur, the most adhesive of the sulfurs, at the standard-recommendation of 2–100 should also be the most effective material. The wettable sulfurs of 5 micron or less particle size, as a class, gave good results with regularity. Of these tested, the flotations paste type seemed best, possessing the advantages of better adherence to smooth foliage and thru light rainfalls before drying. Conversely, the data suggest that materials of greater particle size may be correspondingly less dependable under critical tests (Ser. 1).

Amendments added to sulfur to promote adhesiveness seem to have particular value in rust control. For instance, with Kolofog the included bentonite has caused the sulfur to stick sufficiently under adverse conditions to give immediate and excellent protection (Ser. 1). It is conceivable, however, that because of changes in the physical nature of the bentonite when wetted and redried, materials containing bentonite may give immediate protection and yet may not be protective against further rains. Again, the presence of iron oxide in the Camden flotation sulfur paste may increase sulfur adhesiveness

and thus be responsible in part for the effective results obtained with it. Concrete evidence on the value of adhesive-promoting additions to the sulfur has been shown in the results obtained with the use of oil (Ser. 2, 3, 4, and 5). In this connection, observations have indicated that the addition of more spreader to some of the wettable sulfurs renders them more effective on smooth-leaved apple varieties, altho an excess of spreader leads to excessive run-off and reduced effectiveness.

SUMMARY AND PRACTICAL SUGGESTIONS

In spite of a prevalent opinion to the contrary, apple rust can be controlled in the Hudson Valley with fungicides. In most seasons and even under conditions of severe disease incidence, it appears that commercial control can be effected economically.

The old standard fungicides, lime-sulfur and bordeaux, will effectively prevent rust infections. The former material, however, may be dangerous from the standpoint of host injury (1) when the trees have been weakened by successive rust epidemics, (2) when heavy applications are repeated at close intervals as is often necessary in rust control, and (3) when weather conditions prevent the spray from drying promptly. Bordeaux is not generally recommended for use on apples in the Hudson Valley because of the risk of copper injury and because of spray residue. Proprietary copper substitutes for bordeaux have not proved satisfactory.

Main reliance for rust control, then, rests with the milder wettable sulfur materials. Of this general class, those products of finest sulfur particle size have proved most dependable. In this connection, sulfurs of 325-mesh fineness may not be effective in critical situations. Preference should be given to the still finer sulfurs, with particles of 5 microns or less in diameter. Of the flotation sulfurs the paste forms have seemed more effective than the dry form. Amendments to the sulfur that increase adhesiveness apparently increased effectiveness.

A spray program for apple rust control fits in with the usual program employed against scab. In fact, in the majority of Hudson Valley orchards, the scab sprays also take care of rust. Where rust is a real problem, however, additional sprays must be interpolated.

The spores of the apple rust fungus may be discharged any time between the latter part of April and the latter part of June, which

period coincides with the ascospore discharge by the apple scab fungus. Apple rust infection, however, can take place without apple scab infection, and *vice versa*. As in scab control, the important factor in rust control is to have the sprays precede the wetting periods during the season of spore discharge, particularly at the strategic times in foliage and fruit development. Timeliness and thoroness in spraying are even more essential with rust than with scab, since the amount of spore inoculum is apt to be much heavier and since the rust fungus cannot be eradicated from the host tissues by lime-sulfur sprays applied after wetting periods.

Frequency of spray applications for rust prevention is not determined by days, but by the rate of apple tree growth and by occurrence of wetting periods. Thus, in the early growing season, as from pink to bloom, the intervals between sprays may be only 3 days or less, whereas later, as growth slows up, the intervals may be lengthened with comparative safety to 5 to 7 days, and still later, to 10 to 12 days. Failure to have fruits and foliage protected with a fungicide from the unfolding of the cluster buds to petal fall may be very serious, particularly if the trees are in poor vigor. A few days after petal fall, the young fruits are past their susceptible period and terminal growth is usually not much more than two new leaves per week. With blocks of vigorous trees that have received an adequate spray schedule up to this point, missing one spray during an infection period in late May or June will not usually be of serious consequence.

While intensive spraying will give perfect control, for practical reasons growers should be content with commercial control. The number of sprays required depends largely on the ability of the operator to forecast the weather, the condition of the orchard, and the efficiency of the spray equipment. Effective coverages, spraying from outside only, can be rapidly applied on short notice if the trees are sufficiently pruned and the spray equipment is of adequate capacity. In emergencies, dusting thoroly with the proper material should give good results. Frequent applications are an insurance measure and are especially important where rust is really serious. If costs must be kept down, materially lower concentrations applied timely and thoroly are advised rather than less frequent spraying or skimpy spraying with higher concentrations. After all, spraying for the control of apple rust is essentially the same as controlling scab with wettable sulfurs.

More specifically, the sprays for scab as advised by the Farm

Bureau spray service in each county will take care of the rust problem also until bloom. The bloom period, however, is another matter. The fruits are most susceptible between the early pink stage and petal fall or shortly after. Frequently, also, considerable new leaf growth is developed at this time if weather conditions delay blooming or prolong the bloom period if the variety is a long-blooming sort. Too, the pink spray is frequently applied early. As a consequence, a wettable sulfur spray which may be important in scab control during bloom is especially advisable for cedar rust control. Of course, it is best to make sure first of one or two good pollinating days before making the application. There is little risk, however, in spraying during bloom, especially with self-fertilizing varieties, because the apple blossoms never all open at the same time and because very little of the spray adheres to the flower parts.

The standard scab spray schedule after bloom calls for an early petal fall spray, one 10 days or so later (latter part of May) and one the middle of June (first codling moth spray). The apple rust spray program may necessitate two additional sprays, the first between the early petal fall spray and the 10-day spray, to insure against both fruit and foliage infection; and the second between the 10-day and codling moth sprays for foliage protection mainly.

Individual growers who find it impossible to control the apple rusts by the foregoing spray schedule have still two other alternatives, *viz.*, to remove the cedars or to replace with rust-resistant sorts.

Commercial control should be achieved by the complete eradication of the cedars within a radius of ½ mile of the apple orchard. This control measure, however, does not assure complete protection as the spores may be carried several miles. Location of the source of inoculum, prevailing wind direction, natural barriers, and continued humidity at time of wetting periods, all tend to offset or vary the results. However, a high degree of protection may be expected and certainly the inoculum will be cut down, which should materially aid in commercial control. Susceptible apple trees which are nearest diseased red cedars are liable to heaviest infections, but the number of infections usually decreases rapidly with increased distance from the cedars. Since it rarely happens that all of the cedars are infected, it might be practical to remove only the diseased ones.

In many instances, for various reasons, eradication of the cedars is impractical or impossible and in such cases the only solution of the problem is the planting of resistant varieties, the most promising of

which are Milton, McIntosh, and Cortland. Altho this control method results in loss of crop for several years, eventually such orchard replacements may prove highly profitable since many of the apple varieties seriously susceptible to apple rust have but a limited commercial value.